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(YIP-09) Improving Synthesis and Recognition of Crowded Scenes using Statistical Models of Group Behavior

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14. ABSTRACT

Virtual training environments are an important tool for training military personnel in a cost- effective way, and realistic crowd modeling and population simulation are crucial components for developing training scenarios set in urban environments. The key objectives of this project were to:
1. create computational models of human group behavior;
2. analyze group behavior in simulation environments;
3. synthetically generate realistic group behavior in software agents;
4. simulate populations in large urban settings using agent-based models.
In the future, these models will enable software developers to significantly improve the realism of agents in military simulations and the accuracy of behavior recognition in surveillance applications by better characterizing how social context affects action selection

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(YIP-09) Improving Synthesis and Recognition of Crowded Scenes using Statistical Models of Group Behavior

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Abstract

Virtual training environments are an important tool for training military personnel in a cost-effective way, and realistic crowd modeling and population simulation are crucial components for developing training scenarios set in urban environments. The key objectives of this project were to:

1. create computational models of human group behavior;
2. analyze group behavior in simulation environments;
3. synthetically generate realistic group behavior in software agents;
4. simulate populations in large urban settings using agent-based models.

In the future, these models will enable software developers to significantly improve the realism of agents in military simulations and the accuracy of behavior recognition in surveillance applications by better characterizing how social context affects action selection for humans in group settings.

Summary of Work

Work on this project was organized into three subtasks: 1) analysis and recognition of human group behaviors in virtual worlds and social media using machine learning, 2) constructing agent-based models for realistically simulating a range of individual and group behaviors, 3) evaluating the performance of a large-scale agent-based model initialized with human data at predicting transportation behavior in urban settings. Detailed information on each of these efforts can be found in the completed publications in the reference list and downloaded at `http://ial.eecs.ucf.edu/publications.php`.

Analyzing Human Group Behavior

In our initial work, we focused on the use of spatial patterns to identify the changing teamwork structure of human teams participating in simulated MOUT (Military Operations in Urban Terrain)

scenarios [15]. But in many situations, communication is a better predictor of group structure than spatial patterns.

Thus to analyze communication patterns, we developed a new algorithm for extracting social connections from unstructured chat data SSTO (Shallow Semantic Temporal Overlap) and evaluated it on a dataset of 80,000 utterances collected from the virtual world, Second Life. The core of SSTO is a rule-based system that relies on shallow semantic analysis of linguistic cues that commonly occur in chat data, including mentions of named entities as well as the temporal co-occurrence of utterances, to generate a to/from labeling for chat dialogs with directed links between users [11, 12].

One of the problem is that using temporal overlap alone as a cue for detecting links can produce extraneous links and low precision. To reduce these extraneous links, our algorithm uses a combination of community detection and topic modeling to filter extraneous links. Community detection is performed on an initial version of the social network created using the rule-based system alone, and cross-community links are removed from the network when there is insufficient semantic support for a particular link.

The intuition behind the use of topic modeling is that utterances of two players engaged in an ongoing conversation are likely to belong to the same topic. An unsupervised topic model can be extracted from the text of the user utterances using Latent Dirichlet Allocation. By applying this topic model to a specific user's utterances, a player-specific topic distribution can be calculated and directly compared to other players in the virtual world using Kullback-Leibler (KL) divergence. The extended version of SSTO uses this information as a filtering mechanism to whether to retain or discard links identified by temporal overlap. Our results show that the addition of topic information can be useful in improving the performance of SSTO.

Using our algorithms we can identify groups through a combination of physical proximity and communication patterns. According to our findings, the type of activity that the participants are doing in the virtual world has a measurable effect on the social structure that can be captured using univariate or k-core statistics measured from social networks extracted with SSTO [14]. Topics can also form a useful cue for identifying the region in the virtual world where a particular conversation occurred. Our empirical study of region-based user group showed that topics were the single best predictive feature for identifying the region of a user group in Second Life. However, the combination of network and community features can be more predictive of regional differences than the actual topic of the conversation alone. Hence, even if the content of the conversation is unknown the timing and link structure of the social network are very useful cues for the region identification task.

To measure the stability of social groups in Second Life, we performed an analysis using the dynamic actor-oriented model for network evolution; this model can be used to explore the evolution of the network (mined from the dialog exchanges) considering the community membership from previous time period as an actor attribute. This test gives us statistical evidence whether the community membership persists over time and provides additional support on the accuracy of our community detection. Using longitudinal network data analysis, we consider sequences of network observations extracted from dialog exchanges, along with attributes of the SL avatars, and model them in an actor-oriented model using RSiena (Simulation Investigation for Empirical Network Analysis). The methodology has been successfully employed in a number of sociological studies on the influences of different factors on group behavior. We found that the community membership from the previous time period was a useful predictive factor for identifying which users will form

links in future timesteps. This indicates that the community structure in Second Life persists over longer time periods (hours and days), despite the large number of transient users [10].

Our software toolkit for analyzing user activities in Second life is described at [13], and our code for SSTO can be downloaded at: `http://code.google.com/p/shallowsemantictemporaloverlap/`.

Agent-Based Models of Individual and Group Behaviors

For this subtask, our aim was to develop generative models of human behavior specifically for simulating realistic human populations. Agent-based simulations can be an important tool for modeling social systems, enabling researchers to examine phenomena that are difficult to study empirically. Rather than simply employing standard utility-based methods for programming rational agents, our agents are constructed using human psychological models and are designed to continuously factor the presence of other agents into their decision-making. The agents compete against other agents playing social games [5] or cooperate with other agents to achieve team tasks. In our studies, the agents were evaluated both on social verisimilitude as well as task performance.

After constructing some initial prototype agents, we developed a larger agent-based simulation for investigating the impact of social factors on the formation and evolution of task-oriented groups. Group membership influences many aspects of our lives, including our self-identities, activities, and associates; it affects not only what we do and who we do it with, but what we think of ourselves and the people around us. It can also give rise to stereotypic thinking in which group differences are magnified and the importance of individual variations are discounted.

For this subtask, we examined the impact of social phenomena such as stereotype on the structure of the network. The social system is simulated using an adaptive network that modifies its structure based on the agents' experiences. In our experiments, we quantified how the network structure affects group formation and task accomplishment of agent teams. Interestingly, even without assuming that stereotypes affect the agents willingness or ability to complete tasks, the long-term modifications that stereotypes have on the agents social network impair the agents ability to form groups with sufficient diversity of skills, as compared to agents who form links randomly [6].

Using this generative model of group behavior within a social network, we examined the problem of influence maximization in a larger agent community, under the assumption that the agents possess realistic models of group identify and also have correlated beliefs about issues. The goal of the influence maximization process is to improve the effectiveness of communication to a large community by identifying effective messenger agents in a network. Our optimization technique for this problem outperforms other network analysis methods while accounting for realistic factors such as group membership and preference correlations [7, 8, 9].

Urban Agent-Based Simulation

For the final subtask, we constructed a large-scale agent-based simulation and used it to model the student population on the University of Central Florida Orlando campus [1]. Urban simulation is a particularly fertile area for agent-based simulation research since it requires modeling a large number of interdependent agents making sequential decisions within a small region. To perform transportation forecasting on the UCF campus, we created an agent-based model for simulating the common activities (transportation, dining, recreation, and building occupancy) performed by the 47,000 students on the main campus. Our initialization method of combining agent-based models

with survey data allows us to streamline model creation, making the process more automatic. The code for our simulation can be downloaded at: `http://code.google.com/p/ucf-abm/`

Personnel

In addition to the PI, three graduate students worked on this project: Fahad Shah, Mahsa Maghami, and Xi Wang. Fahad Shah completed his dissertation which can be downloaded at: `http://ial.eecs.ucf.edu/pdf/ShahPhD2011.pdf`.

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